



The Dark Energy Survey (DES)

Huan Lin
Experimental Astrophysics Group
Fermilab

On behalf of the Dark Energy Survey Collaboration



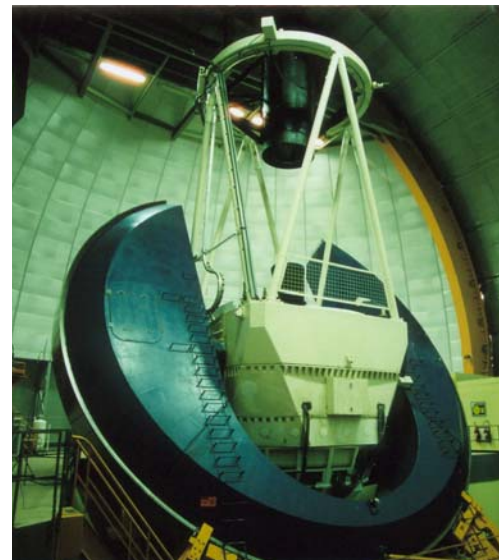
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The Dark Energy Survey (DES)

- **Proposal:**
 - Perform a 5000 deg² *griz* survey of the Southern Galactic Cap
 - Study dark energy using 4 complementary techniques: *galaxy clusters, weak lensing, galaxy angular power spectrum, and Type Ia supernovae*
- **New Instrument:**
 - Large 3 deg² mosaic CCD camera and optical corrector for the CTIO 4m Blanco telescope
 - Construction 2005-2009
- **Survey:**
 - 30% of the telescope time from 2009-2013
 - Data released to public within a year of observations



Image credit: Roger Smith/NOAO/AURA/NSF



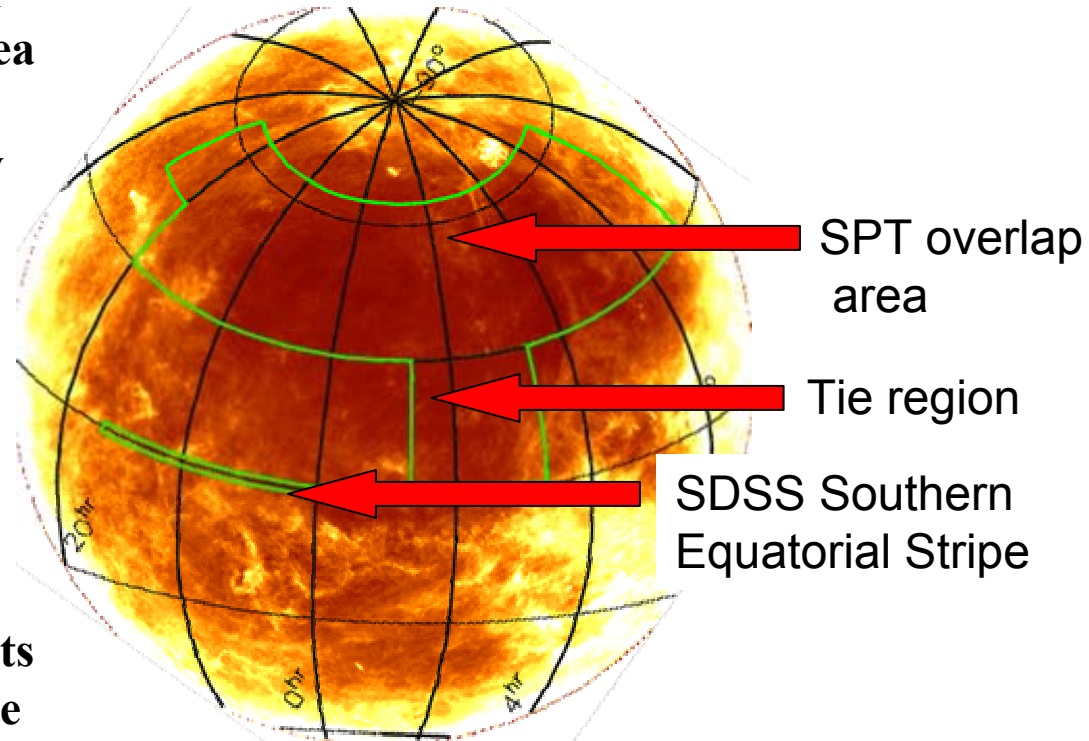
**Blanco 4m Telescope
at the Cerro-Tololo
Inter-American
Observatory (CTIO)**



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Basic Survey Parameters

- **5000 deg² Survey Area**
 - 4000 deg² of overlap with South Pole Telescope (SPT) survey area
 - Also includes SDSS Southern Equatorial Stripe + deep galaxy redshift survey fields
- **Limiting Magnitudes**
 - Galaxies: 10σ *griz* = 24.6, 24.1, 24.3, 23.9
 - Point sources: 5σ *griz* = 26.1, 25.6, 25.8, 25.4
- **Observation Strategy**
 - Multiple tilings/overlaps (in units of 100 sec exposures) to optimize photometric calibrations
 - 2 survey tilings/filter/year
 - 1% photometry goal

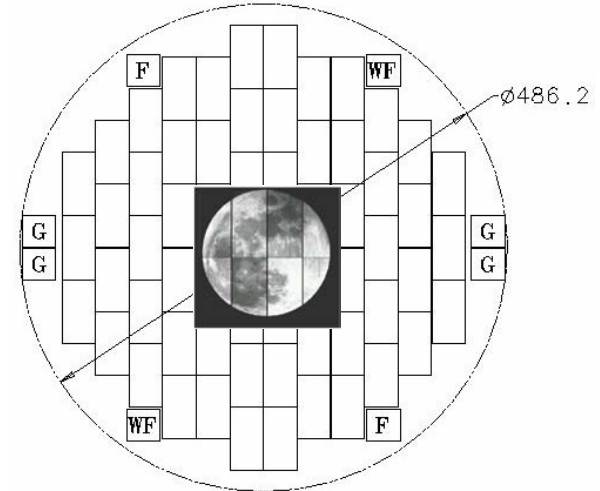
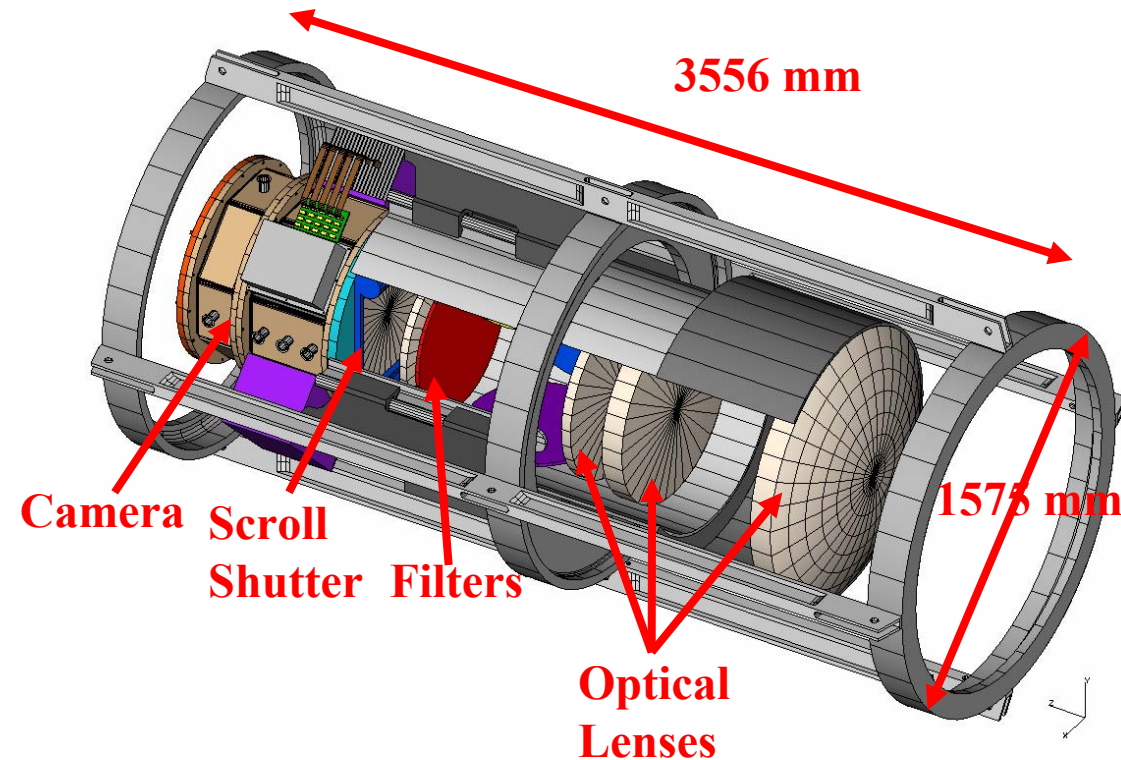




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The DES Instrument

- 5-element optical corrector
- 4 filters: g, r, i, z
- 2k x 4k LBNL CCDs
- 0.27"/pixel
- 62 CCD, 520 Megapixel mosaic camera
- 3 deg² field of view

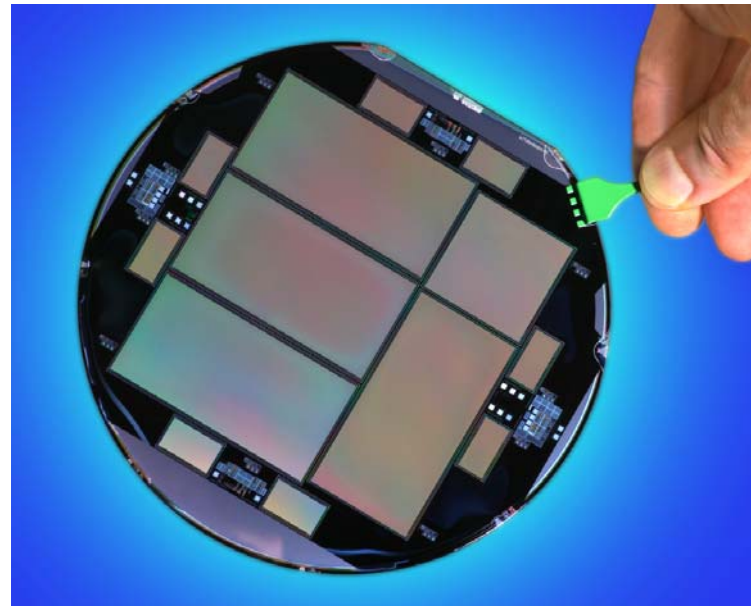
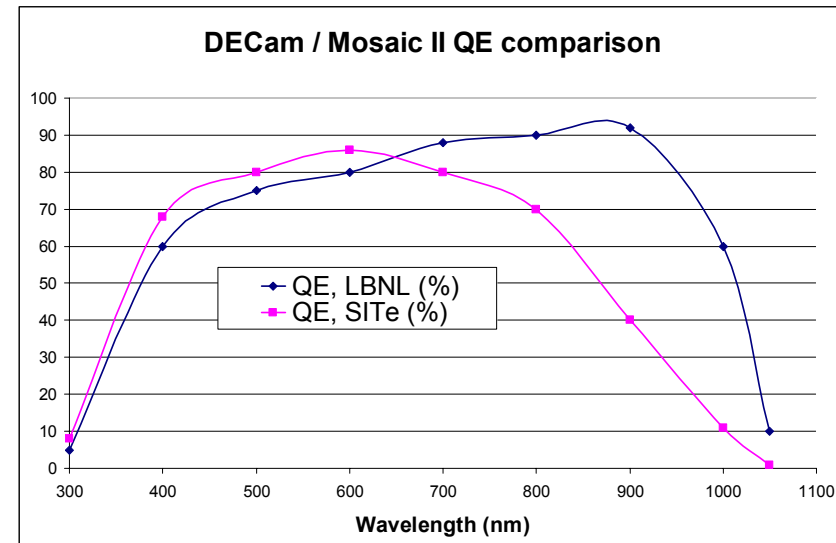




DES CCDs

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- **LBNL CCDs**
 - High quantum efficiency in the red:
QE > 50% at 1000 nm
 - 250 μm thick, 15 μm pixels
 - 17 sec readout time
 - Optimal for z-band observations
needed by DES for galaxies and
clusters at redshifts ~ 1 and above
- **DES CCD wafers**
 - First lots have been delivered by
Dalsa and finished by LBNL
- **First devices are now being
packaged, tested, and
characterized at Fermilab**



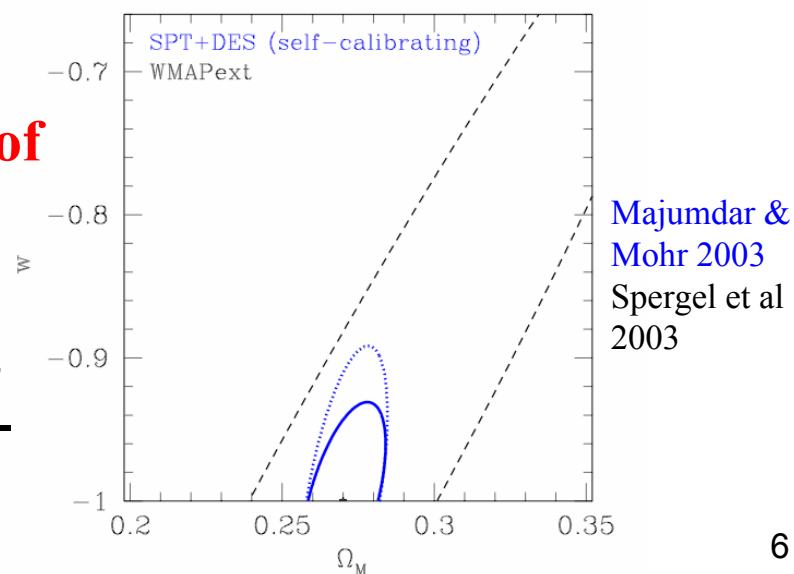
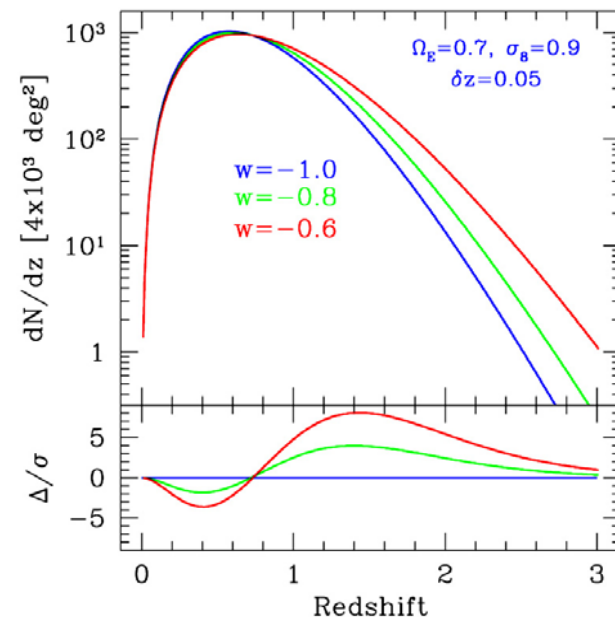


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DES: Galaxy Clusters

Galaxy cluster abundance, mass function, and correlations sensitive to cosmology via effects on volume and on growth rate of perturbations

- **Complementary cluster samples**
 - DES optical data provide accurate cluster photometric redshifts
 - South Pole Telescope (SPT) Sunyaev-Zel'dovich (SZ) data provides robust cluster masses
 - **~30000 clusters in 4000 deg² area of DES-SPT overlap**
- Multiple cluster mass estimators (SZ, optical luminosity, lensing) and cross-checks of sample selection effects

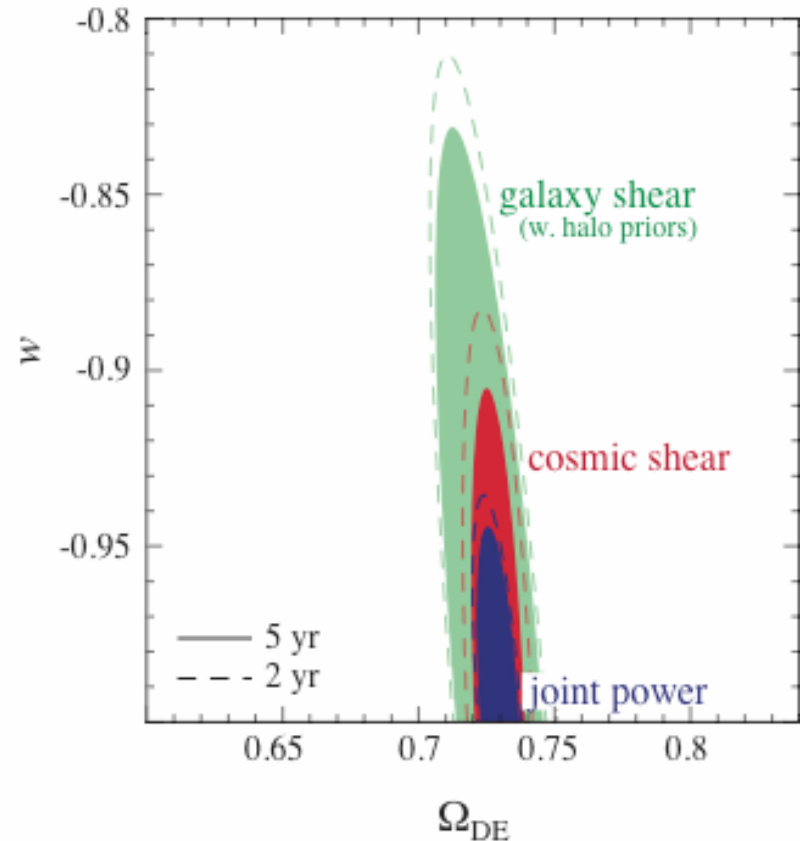




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DES: Weak Lensing

- **Measure shapes for ~300 million source galaxies**
 - Average galaxy redshift ~ 0.7
 - Effective galaxy surface density of ~ 10 per arcmin²
- **Shear-shear and galaxy-shear correlations probe distances and growth rate of perturbations**
- **Also provides independent calibration of cluster masses**



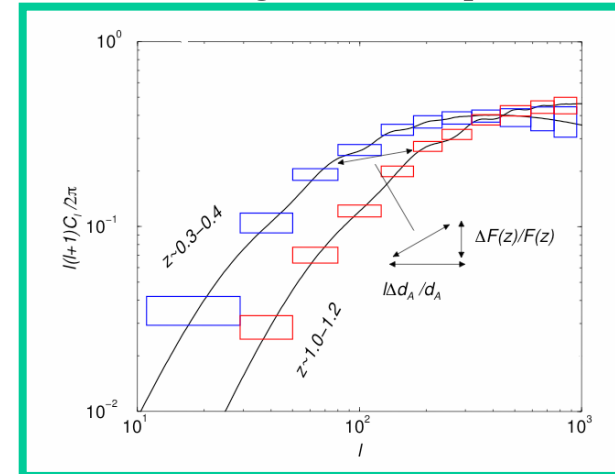


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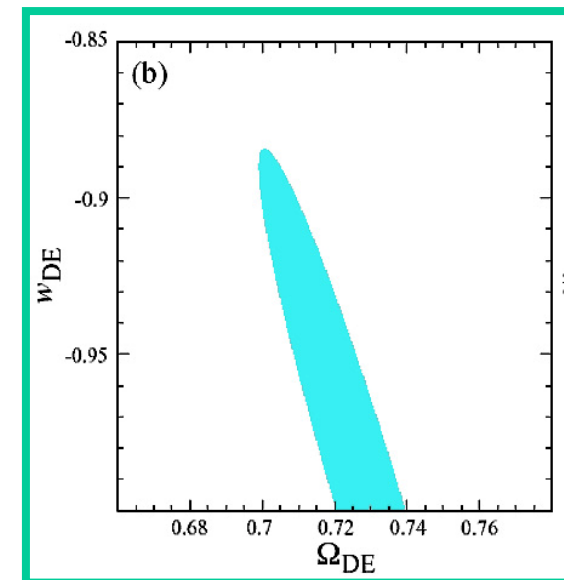
DES: Angular Power Spectrum

- **Angular power spectrum of 300 million galaxies over 5000 deg²**
 - Measured in photo-z bins out to redshifts of 1 and above
- **Features in the angular power spectrum** (e.g. horizon scale at matter-radiation equality, baryon oscillations) **provide physically calibrated “standard rods”**
- Allows measurement of angular diameter distances as a function of redshift to constrain cosmology

Cluster Angular Power Spectrum



Cooray et al ApJ 2001



Wayne
Hu 2004

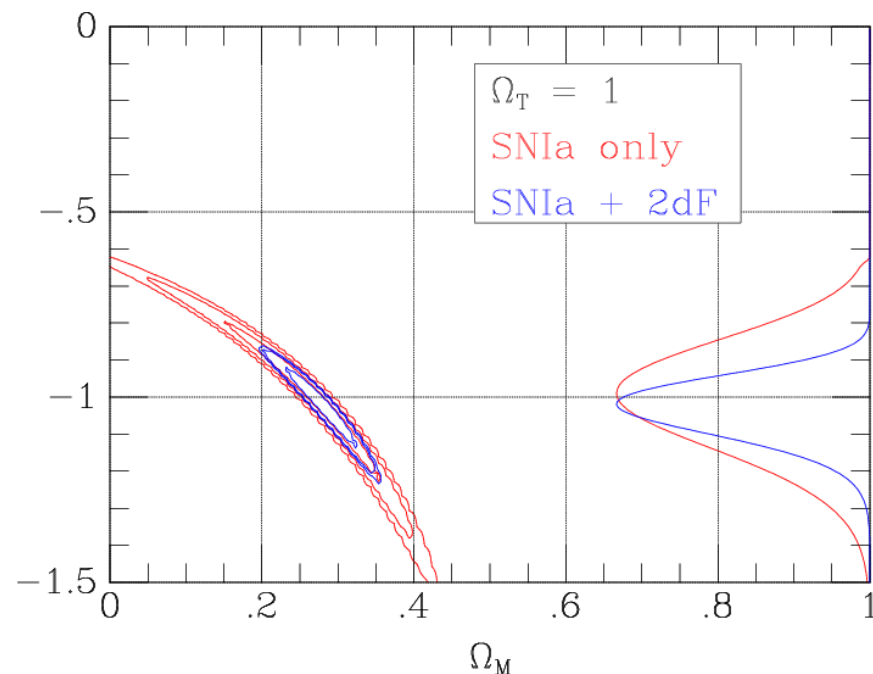


DES: Type Ia Supernovae

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**Repeat observations of 40 deg²,
10% of survey time**

- **~2000 well-measured SN Ia light curves, $0.25 < z < 0.75$**
- **Larger sample, improved z-band response compared to ESSENCE^w and CFHTLS**
- **Combination of spectroscopic (~25%) and photometric redshifts**
- **Develop color typing and SN photo-z's (critical for LSST)**



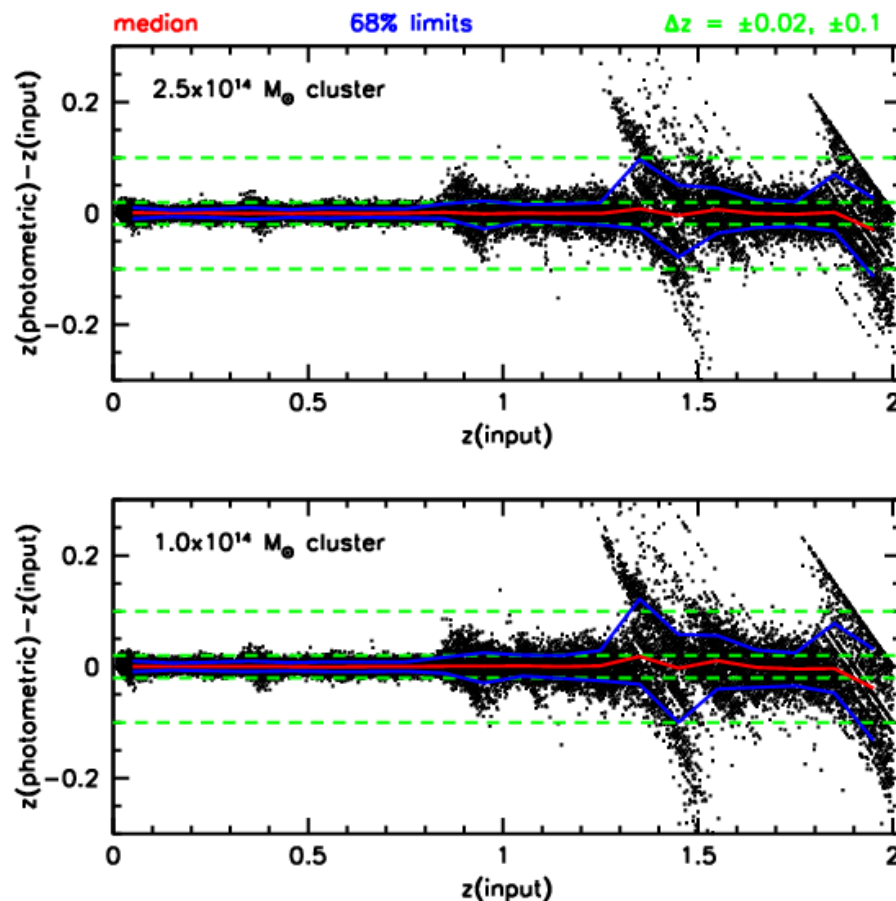


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DES Photometric Redshifts

- **Clusters:** robust photo-z's to redshifts ~ 1.3 , with 68% scatter of 0.02 or less
- **Field galaxies:** 68% photo-z scatter of 0.07 using optimal “comparison” method
- Large completed and ongoing redshift surveys (SDSS, 2dFGRS, VVDS, DEEP2) will provide $\sim 250,000$ redshifts for calibrating photo-z's and characterizing error distributions in detail
- Actively working to improve mock galaxy and cluster catalogs, understand photo-z errors, and derive photo-z requirements set by cosmological parameter analyses

DES cluster photo-z simulation





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DES Dark Energy Constraints

**Forecast statistical constraints on
constant equation of state parameter w models
(DES DETF white paper, astro-ph/0510346)**

- **4 Dark Energy Techniques**
 - Galaxy clusters
 - Weak lensing
 - Angular power spectrum
 - Type Ia supernovae
- **Statistical errors on constant w models typically $\sigma(w) = 0.05-0.1$**
- **Complementary methods**
 - Constrain different combinations of cosmological parameters
 - Subject to different systematic errors

Method/Prior	Uniform	WMAP	Planck
Galaxy Clusters: abundance w/ WL mass calibration	0.13 0.09	0.10 0.08	0.04 0.02
Weak Lensing: shear-shear (SS) galaxy-shear (GS) + galaxy- galaxy (GG) SS+GS+GG SS+bispectrum	0.15 0.08 0.03 0.07	0.05 0.05 0.03 0.03	0.04 0.03 0.02 0.03
Galaxy angular clustering	0.36	0.20	0.11
Supernovae Ia	0.34	0.15	0.04



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DES Project Status

- **1st Collaboration Meeting Dec. 2003**
- **July 2004: Fermilab Director gives DES Stage 1 approval**
 - **Fermilab resources can be used for R&D**
- **Aug 2004: NOAO Director accepts DES proposal for partnership**
 - **525 nights of CTIO 4m time in return for new instrument and archive**
- **May 2005: Science working groups form**
 - **write Dark Energy Task Force white paper (astro-ph/0510346)**
- **FY05 and 06 are R&D years**
 - **CCDs: establish yield, learn to test CCDs, demonstrate packaging**
 - **25 wafers in FY2005 and FY2006**
 - **Optics: finalize design, develop firm cost estimate**
 - **order glass in FY2006, figure and polish in FY2007**
- **FY07 and FY 08 are construction years**
- **Jan 2009: ship instrument to Chile**
- **Sept 2009: start survey**



The DES Collaboration

61 scientists at 12 institutions

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Fermilab: J. Annis, H. T. Diehl, S. Dodelson, J. Estrada, B. Flaugher, J. Frieman, S. Kent, H. Lin, P. Limon, K. W. Merritt, J. Peoples, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester.



University of Illinois at Urbana-Champaign: C. Beldica, R. Brunner, I. Karliner, J. Mohr, R. Plante, P. Ricker, M. Selen, J. Thaler



University of Chicago: J. Carlstrom, S. Dodelson, J. Frieman, M. Gladders*, W. Hu, E. Sheldon, R. Wechsler. * Carnegie Observatories until summer 2006



Lawrence Berkeley National Lab: G. Aldering, N. Roe, C. Bebek, M. Levi, S. Perlmutter



NOAO/CTIO: T. Abbott, C. Miller, C. Smith, N. Suntzeff, A. Walker



Institut d'Estudis Espacials de Catalunya: F. Castander, P. Fosalba, E. Gaztañaga, J. Miralda-Escude



Institut de Fisica d'Altes Energies: E. Fernández, M. Martínez



University College London: O. Lahav, P. Doel, M. Barlow, R. Bingham, S. Bridle, S. Viti, J. Weller



University of Cambridge: G. Efstathiou, R. McMahon, W. Sutherland

University of Edinburgh: J. Peacock



University of Portsmouth: R. Nichol



University of Michigan: R. Bernstein, A. Evrard, D. Gerdes, T. McKay